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Role of MRI in diagnosis of pulmonary embolism

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Abstract

Background Pulmonary embolism (PE) is considered a serious condition and has clinical challenges in diagnosis. Computed tomography pulmonary angiography (CTPA) is considered the gold standard in PE diagnosis. Contrast-enhanced MRA also has a strong useful role in the diagnosis. Our study aims to assess the role of non-contrast MRA in diagnosis of acute pulmonary embolism compared to either CT pulmonary angiography or contrast enhanced MRA.

Results In total, 50 patients with PE confirmed by either CTPA or CE-MRA were included in this study. All patients underwent non-contrast MRPA during the three consecutive days after CTPA or at the same examination setting in CE-MRA. The results were compared and statistically analyzed.

The mean age of our study group was 47.80 ± 14.01 years. Males represented 56% (28/50) and females 44% (22/50). The per-vessel sensitivity, specificity and accuracy of non-contrast MRPA reached about 100% for each parameter at the level of the pulmonary trunk, main pulmonary and lobar arteries. At the segmental level, sensitivity, specificity, and accuracy reached about 88%, 100%, and 94%, while at the subsegmental level, about 35%, 100%, and 66% respectively. The overall sensitivity, specificity, and accuracy of non-contrast MRPA regardless of the site were 84%, 100%, and 90% respectively.

Conclusions Non-contrast pulmonary MRA has a high sensitivity and specificity in the diagnosis of PE, especially in proximal pulmonary arteries. So, it can be used as an alternative to the CTA and CE-MRA, especially when the CTA and the use of gadolinium are contraindicated.

Keywords MRI, Diagnosis, Pulmonary embolism, Multi-slice CT, CT pulmonary angiography

Background

Pulmonary embolism is a dangerous clinical condition that can lead to significant morbidity and mortality. It is currently considered the third cause of cardiovascular deaths all over the world. That is why it needs accurate diagnosis and treatment to prevent dangerous outcomes [1].

Pulmonary embolism occurs if a blood clot, mostly from the leg migrates to the lung and occludes the pulmonary artery or one or more of its divisions [2].

The diagnosis of acute PE is actually a clinical challenge due to its variable multiple non-specific signs and symptoms [3]. The D-dimer results could be frequently false positive in many other clinical conditions rather than PE such as neoplastic and inflammatory processes [4].

CT pulmonary angiography (CTPA) has a high sensitivity and specificity in the diagnosis of PE and has been considered the imaging technique of choice in patients

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with suspected pulmonary embolism. Multi-slice CT has a high spatial and temporal resolution imaging in a short time scan. In addition, CTPA is able to assess the pulmonary tree down to the fifth and to eighth branching level in a short time (less than 15 s) due to its high imaging speed [5].

MRI is recognized as a potential alternative diagnostic technique to CTPA in the assessment of the pulmonary vascular tree and diagnosis of PE [6]. Up to date, however, most of the studies evaluating the use of MRI in the diagnosis of PE have been designed to use gadolinium based intravenous contrast media that is contraindicated in certain situations such as pregnant patients and in those with renal failure [7].

The aim of this study is to assess the role of non-contrast MRA in diagnosis of acute pulmonary embolism compared to either CT pulmonary angiography as the gold standard technique or CE-MRA as an effective alternative diagnostic test for PE diagnosis.

Methods

This prospective study was performed at the radiodiagnosis department, Assiut University Hospitals, Assiut, Egypt. From October 2020 to October 2022 on 50 patients with one or more clinical manifestations of pulmonary embolism. These patients were examined by CTAP and magnetic resonance imagining.

Inclusion criteria

High or intermediate clinical probability of PE assessed by the revised Geneva score or having a D-dimer level > 500 µg L1 on an ELISA-based test and according to European Society of Cardiology (ESC) guidelines for the diagnosis of clinically suspected PE.

Patients clinically evident and confirmed by CTPA to have PE.

Both sexes were included.

No randomization or selection was done.

No age predilection was considered but patients less than 18 years old were not included.

Exclusion criteria

Contraindications for MRI such as metallic ocular implant, implanted magnetizable device, cardiac pacemakers, and claustrophobic patients.

Patients with bad general condition with signs of severe PE such as hemodynamically unstable patients that were excluded.

Patients underwent full history taking and clinical examination.

Two groups of patients were encountered. Group A (35 patients): patients who have been already examined by CTPA for pulmonary embolism then non-contrast MRPA was done maximally within the next 3 days. Group B (15 patients): patients who were clinically suspected to have pulmonary embolism and did not do CTPA. In this patient group, non-contrast MRA was done first, followed by contrast enhanced MRPA in the same examination setting as CE-MRA is effective alternative test to CTA for the primary diagnosis of PE.

Technique of non-contrast MRPA examination

MRI study was performed by using a 1.5-T MR system (Magnetom Avanto; Siemens Medical Systems, Erlangen, Germany). Patient position was supine and examination time was 10–30 min. Examination protocol: Non-contrast technique and depending on white blood (WB) and black blood (BB) sequences with ECG and respiratory gating.

Real-time MRI

Three real-time fast true imaging with steady-state free precession MRI sequences (also called balanced fast-field echo and fast imaging using steady-state acquisition) was the first step of the protocol. Images were acquired in single-shot technique which minimized motion artifacts by limiting them to the short acquisition time of each single image (acquisition time range per image was 0.4–0.5 s; TR/TE, 3.1/1.5; flip angle, 59°; band width, 975 Hz/pixel). Within three minutes, 320 slices of 50% overlap were obtained in three orthogonal orientations: 120 transverse slices (thickness of 3 mm, 340 mm field of view, matrix size, 256 × 156) this is followed by 100 coronal slices (thickness of 4 mm; field of view, 360 mm; matrix size, 256 × 192) and 100 sagittal slices (thickness, 4 mm; field of view, 360 mm; matrix), Size; 256 × 180 pixels). The region from the lung apex down to the diaphragm has been covered by transverse slices, and the region from the manubrium sterni to the spinous process was imaged with coronal slices. The inherent T2 contrast made it possible to discriminate embolus and blood without the aid of contrast agents.

Statistical analysis

Data were collected and analyzed by using SPSS (Statistical Package for the Social Science, version 20, IBM, and Armonk, NY). Quantitative data with normal distribution were expressed as mean ± standard deviation (SD). Nominal data were given as number (n) and percentage (%). Accuracy of MRI in detection of pulmonary embolism was tested by receiver operator characteristics (ROC) curve. Level of confidence was kept at 95% and hence, P value was considered significant if < 0.05.

Image interpretation

The images were transferred to the workstation for interpretation (Siemens MRI Celsius M470 Power Workstation, PN 10498078).

Non-contrast MRI images had been examined by two consultant radiologists having special experience in PE diagnosis. These radiologists were blinded about the CTA and post-contrast MRA findings. The findings of PE at MRPA were intraluminal filling defects, blood vessel cutting, pulmonary artery dilation, and caliber change of the examined vessels.

The image quality was degraded by a number of artifacts. The image artifact that caused the most degradation of image quality is respiratory motion artifact. This artifact can only be alleviated by obtaining images when respiratory motion is minimal. Another artifact is the truncation or Gibbs ringing artifact which is the most challenging artifact because it can mimic PE. Most radiologists are familiar with this artifact in the setting of spine MRI or with MRCP and it was not a diagnostic challenge.

Results

The mean age of our study patient group was 47.80 ± 14.01 years with a range between 16 and 87 years old. Out of the studied patients, 28 (56%) patients were males and 22 (44%) patients were females. There were 9 (18%) patients with surgical history (six patients had fracture femur and three patients had complicated appendicitis) and another 7 (14%) patients with medical history (three patients had COPD and four patients had SLE) (Table 1).

The most frequent risk factors for pulmonary embolism in the studied patients were hypercoagulable state (34%), immobilization (28%), and obesity (24%). COVID-19 infection is present in 10 (20%). Six (12%) patients had malignant lesions, 3 (6%) patients had a history of hormonal therapy and another 3 (6%) patients were on oral contraception (Table 2).

Table 1 Baseline data of studied patients

	N **= 50**
Age (years)	47.80 ± 14.01
Range	16–87
Sex	
Male	28 (56%)
Female	22 (44%)
Surgical history	9 (18%)
Medical history	7 (14%)

Data expressed as frequency (percentage), mean (SD), range

Table 2 Risk factors of pulmonary embolism in studied patients

	N **= 50**
Hypercoagulable state	17 (34%)
Immobilization	14 (28%)
Obesity	12 (24%)
COVID-19 infection	10 (20%)
Cancer	6 (12%)
Hormonal treatment	3 (6%)
Oral contraceptive	3 (6%)

Data expressed as frequency (percentage)

It was found that 43 (86%), 32 (64%), and 13 (26%) patients were presented with dyspnea, chest pain and hemoptysis respectively (Table 3).

For detection of pulmonary embolism regardless of its site, it was found that MRI has 84% sensitivity, 100% specificity and 90% overall accuracy with area under curve was 0.92 (Table 4).

It was found that MRI has 100% sensitivity, 100% specificity, and 100% overall accuracy in detection of central and lobar pulmonary embolism. For detection of segmental pulmonary embolism, it was found that MRI has 88% sensitivity, 100% specificity, and 94% overall accuracy with area under curve (AUC) was 0.94, while for detection of subsegmental embolism, it has 34.6% sensitivity, 100% specificity, and 66% overall accuracy with AUC was 0.67 (Table 5, Figs. 1, 2, and 3).

Table 3 Clinical presentation among studied patients

	N **= 50**
Dyspnea	43 (86%)
Chest pain	32 (64%)
Hemoptysis	13 (26%)

Data expressed as frequency (percentage)

Table 4 Accuracy of MRI in detection of pulmonary embolism regardless the site

Indices	**Value**
Sensitivity	84%
Specificity	100%
Positive predictive value	100%
Negative predictive value	79.2%
Accuracy	90%
Area under curve	0.92
P value	< 0.001

P value was significant if < 0.05. *MRI* magnetic resonance image

Table 5 Diagnostic accuracy of MRI detection of pulmonary embolism

Indices	Site of pulmonary embolism			
	Central (trunk and main)	lobar	Segmental	Subsegmental
Sensitivity	100%	100%	88%	34.6%
Specificity	100%	100%	100%	100%
Positive predictive value	100%	100%	100%	100%
Negative predictive value	100%	100%	89.3%	58.5%
Accuracy	100%	100%	94%	66%
Area under curve	1	1	0.94	0.67
P value	< 0.001	< 0.001	< 0.001	0.02

P value was significant if < 0.05. MRI: magnetic resonance image

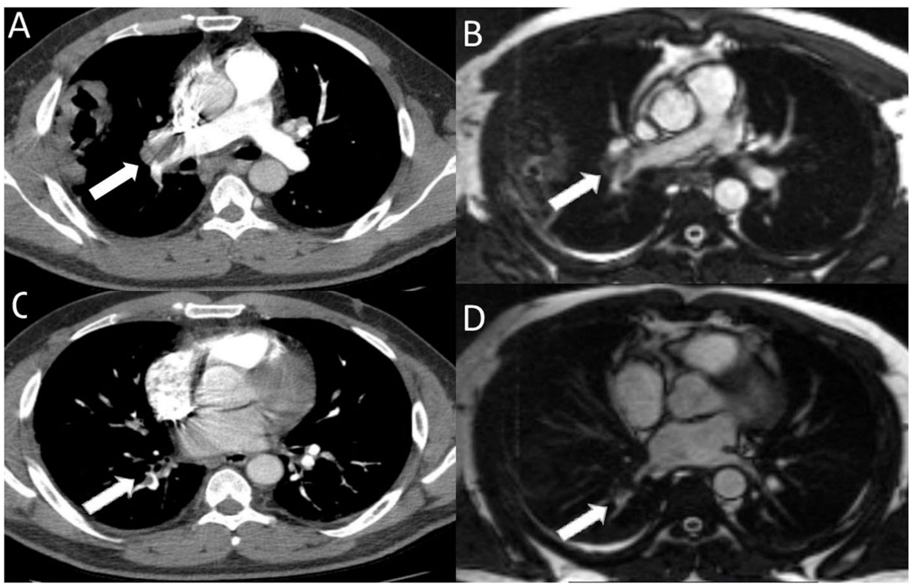

Fig. 1 Female patient 47 years old presented with dyspnea and chest pain. **A**, **C** Axial CT images demonstrate pulmonary embolism near totally occluding the right main pulmonary artery. Also, another smaller PE near totally occluding a segmental branch of the right lower lobe division (arrows). **B** and **D** Non contrast axial MR-PA-WB images obtained 48 h later showing the right main pulmonary embolism of hypointense filling defect (arrow) yet partially occluding the lumen. The embolus involving the segmental branch of the right lower lobe division could be demonstrated in non-contrast MRA

CT and MRI findings other than pulmonary embolism have been mentioned in Table 6. The most frequent findings were pleural effusion in 9 (18%), lung infarction in 6 (12%), pneumonia in 5 (10%) and abscess in 4 (8%).

Discussion

Pulmonary embolism (PE) is a dangerous condition that causes significant morbidity and mortality. PE is currently the third leading cause of cardiovascular death worldwide, so it requires accurate diagnosis and management to prevent potentially deadly consequences [1].

PE is difficult to diagnose clinically because symptoms are non-specific and clinical presentation of patients with suspected PE varies widely from patients who are asymptomatic to those in cardiogenic shock [8].

Our study was designed to compare the accuracy of non-contrast MRPA in PE detection to either CTPA, which is the gold standard or contrast MRPA that is recognized as a potential alternative and effective diagnostic technique to CTPA for primary PE diagnosis in many situations as some patients had mild renal impairment, some gave history of hypersensitivity to iodinated contrast media and others refused CTA due to fear of ionizing radiation.

In this study, we tried to evaluate the non-contrast MRPA technique on 50 patients. The MRI study was

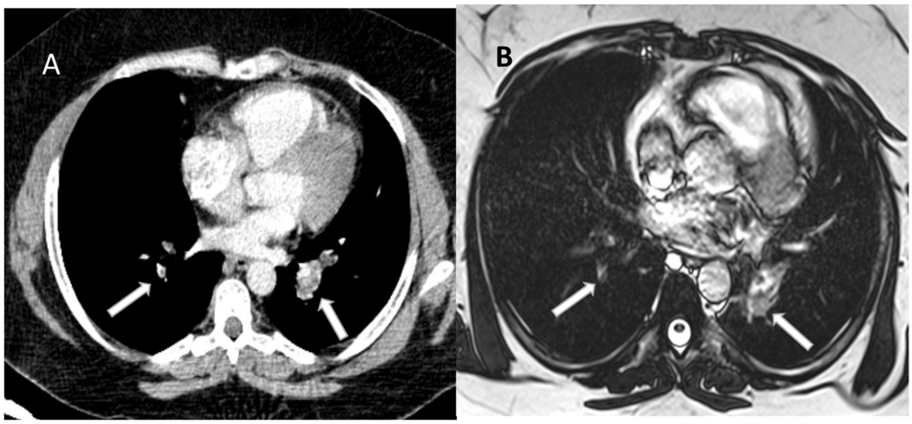

Fig. 2 Female patient 55 years old presented with dyspnea and chest pain. **A** Axial CT image showing pulmonary embolism near total occluding a subsegmental branch of the right lower lobe division and segmental branch of left lower lobe division (white arrows). **B** Axial non contrast MR-PA-WB taken 24 h later reveals the same results with the pulmonary embolism appearing as hypointense matter

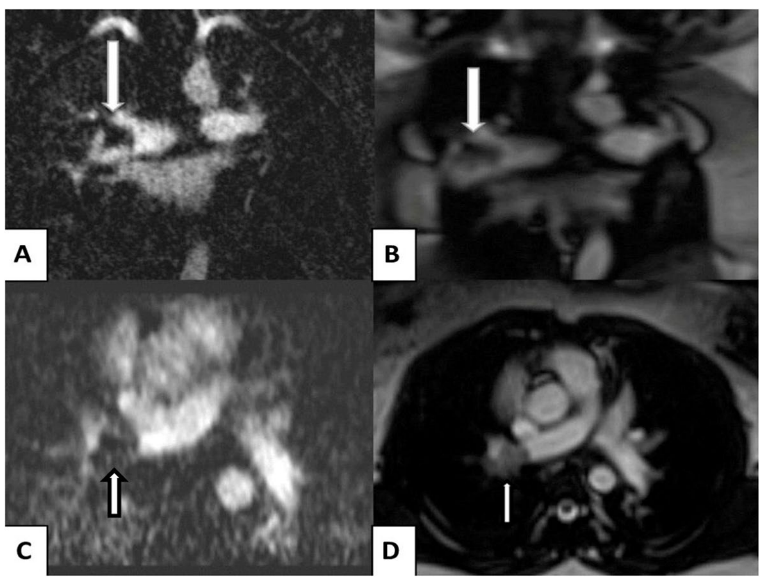

Fig. 3 Contrast enhanced MR angiography (coronal **A** and axial **C** images) showing thrombus at the right main pulmonary artery (arrows). Non-contrast MRA (coronal **B** and axial **D** images) also showed the thrombus (arrows)

performed using a 1.5-T MR system and the examination protocol was non-contrast technique and depended on white blood (WB) and black blood (BB) sequences with ECG and respiratory gating. This is similar to Mohammad et al. (2022) [9] and Mudge et al. (2013) [1], who used the same technique with different numbers of patients. Also, Kluge et al. (2017) [10] and Kalb et al. (2020) [11] tried to evaluate the role of non-contrast MRA in diagnosis of PE.

In our study, the mean patient age was 47.8 (± 14) with male predominance (56% males and 44%females). In their study, Mohammad et al. (2022) [9] showed mean patient age of 46.4 (± 13.5) while Mohamed IS et al. (2017) [12] showed 49 years. Medsona et al. (2019) [13]. showed male predominance in their study while Mohammad et al. (2022) [9] and Mohamed IS et al.(2017) [12] showed female predominance. This can be attributed to the relative small patient number in these studies (25 and 21 patients respectively).

As regarding the risk factor for pulmonary embolism, in our study the most frequent, was hypercoagulable states (encountered in 34% of patients).Tsuchiya et al. (2018) [14], also revealed hypercoagulable states as the most frequent risk factor for PE. 31 of 57 patients were

Table 6 Findings other than pulmonary embolism in studied patients

Findings	CT findings	MRI findings
Pleural effusion	9 (18%)	11 (22%)
Pericardial effusion	2 (4%)	2 (4%)
Lung infarction	6 (12%)	7 (14%)
Pneumonia	5 (10%)	1 (2%)
Pulmonary mass	1 (2%)	2 (4%)
Mediastinal LNs	1 (2%)	2 (4%)
Cardiomegaly	2 (4%)	2 (4%)
Lung abscess	4 (8%)	4 (8%)

Data expressed as frequency (percentage). *CT* computed tomography, *MRI* magnetic resonance image, *LNs* lymph nodes

on anticoagulant therapy for different hypercoagulable states in a study by Medsona et al.(2019) [13]. DVT followed by oral contraceptives were the most encountered risk factors in a study by Mohammad et al. (2022) [9].

In this study, the clinical presentation of patients included dyspnea at 86% followed by chest pain and hemoptysis at 64% and 26% respectively. This agrees with Mohamed IS et al. (2017) [12] who found dyspnea as the most frequent clinical presentation.

Using either CTPA as gold standard techniques or contrast-enhanced MRA as a potential alternative and effective diagnostic technique to CTPA for primary PE diagnosis. The overall sensitivity of non-contrast MRA in detection of PE in this study was 84%, specificity 100%, and accuracy 90%. This is not significantly different from the results of Medsona et al. (2019) [13], especially with different numbers of studied patients.

The per-vessel results in our study, including sensitivity, specificity and accuracy were as follow: for central arteries (trunk and main) and lobar arteries, they were 100% for each parameter, for segmental vessels 88%, 100%, and 94% were encountered and for sub segmental vessels 34.6%, 100%, and 66% were noticed respectively. This clearly matches with the results of Mohammad et al. (2022) [9], Mohamed IS et al. (2017) [12] and Mudge et al.(2013) [1]. Our results are higher than the results obtained by Kalb et al.(2020) [11] who found that the sensitivity of non-contrast MRPA in detection of PE in lobar branches ranged from 40 to 70%. Our sensitivity results are also higher than the results obtained from Mudge et al. (2013) [1] who found that the sensitivity of non-contrast MRPA ranged from 30 to 100%, being 30% at the upper lobar branches and 100% at the lower lobar branches.

As regards the segmental arteries, our results showed 88%, 100% and 94% for sensitivity, specificity and accuracy respectively. While for subsegmental vessels they were 34.6%, 100%, and 66% respectively. These results show no significant divergence from the results of Mohammad et al. (2022) [9]. Mohamed IS et al. (2017) [12], however, showed 50% sensitivity for segmental arteries which could be attributed to the different clinical conditions of the examined patients. The low sensitivity for PE detection at the subsegmental level in our study is attributed to bad image resolution of MRI at the subsegmental branches in comparison to the CT due to breathing motion artifacts.

The false negative results occurred in our study are owing to the low MRPA resolution due to thick image acquisition, breathing motion artifacts due to long examination time and the delay time between non-contrast MRPA imaging and contrast enhanced CTPA (within this period some patients received PE treatment), meaning that fresh emboli could be treated and resolved prior to MRPA examination.

Limitations

Our study is actually limited by the relative small patient number. The study was also limited by the timing of MRI examination. Because MRI was not performed immediately after CTPA, it is possible that by such time delay of MRI, the emboli diagnosed by CTPA had been lysed, especially that the studied patients were on anticoagulant therapy in the period between the CTPA and the MRI. An additional possible limitation of MRI for the evaluation of PE is the relatively longer time required for image acquisition. Although all patients in our study had completed the MRI time of examination except two patients, MRI had longer time than the CTPA. Owing to this time difference, some severely ill patients may not be able to tolerate the MRI.

Conclusion

Non-contrast pulmonary MRA has a high sensitivity and specificity in the diagnosis of PE, especially in proximal pulmonary arteries. So, it can be used as an alternative to the CTA and CE-MRA, especially when the CTA and the use of gadolinium are contraindicated.

Abbreviations

PE	Pulmonary embolism
MRI	Magnetic resonance imaging
MSCT	Multi-slice computed tomography
CTPA	CT pulmonary angiography
MRA	Magnetic resonance angiography
CE	Contrast enhancement

Acknowledgements

Not applicable.

Authors' contributions
HM, AH, HI, MZ, MG, and SA designed the research. HM performed the research and wrote the manuscript. AH and HI analyzed the collected data. MZ, MG, and SA revised the data and manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
Available on request with the corresponding author.

Declarations

Ethics approval and consent to participate
The study was conducted after approval of the Ethical Committee of Faculty of Medicine, and after clinical trial approval (NC703754673). Informed written consent was obtained from each participant.

Consent for publication
All patients included in this study gave a written informed consent to publish the data contained in this study.

Competing interests
The authors declare that they have no competing interests.

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